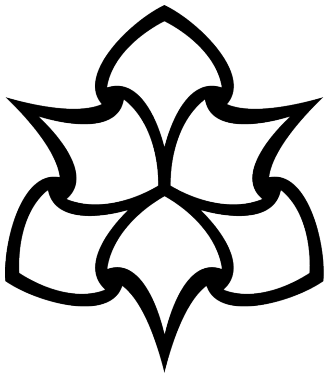

THE ROLE OF FREQUENT ENGAGEMENT IN ALLIANCES IN FIRM LIKELIHOOD TO PATENT: FIRST WAVE ALLIANCES IN UK BIO-PHARMACEUTICALS

Structured Abstract

Purpose

This article explores the role of alliance experience in firm innovation; it argues that, while cumulative alliance experience has a marginally diminishing contribution to likelihood of firm innovation over time, frequent engagement in alliances and an expanding alliance portfolio inhabit an enhancing role. This reveals new dimensions to the role of alliance experience as an antecedent to firm learning in managing alliances and to the development of alliance capabilities.

Design/methodology/approach

The paper estimates a range of models identifying the relationship between alliance experience and firm innovation. The panel data sample captures the full range of firms active in the UK bio-pharmaceuticals sector during the early stages of its development, observing them from 1991 to 2001. An exploratory case study analysis is employed to shed light on the nuanced factors linking frequent engagement in alliances to the development of practices for efficient alliance management.

Findings

The paper shows that cumulative alliance experience has a marginally diminishing contribution to likelihood of firm innovation over time, while frequent engagement in alliances and the ensuing expansion of alliance portfolios, enhance firm innovation. The exploratory case analysis demonstrates a link between frequent engagement in alliances and the development of processes for alliance management that could collectively reflect alliance capabilities.

Originality/value

Our contribution derives from a longitudinal analysis of an original panel dataset that maps the UK bio-pharmaceuticals sector over the initial period of its development. The paper (a) sheds light on factors that can impel firms to form alliance capabilities, and (b) extends a currently thin body of work on the foundations and antecedents to alliance and alliance portfolio capabilities.

Keywords: Strategic Alliances, Alliance Capabilities, Innovation, Panel Data, Bio-Pharmaceutical Sector

JEL Codes: C33, M10, O32, D74

1. Introduction

As the popularity of strategic alliances is increasing and such alliances are becoming an integral component in business development, attention in the research community has moved towards an exploration of their role in firm performance and innovation. Formal and informal interactions with external actors have long being argued to play a fundamental role in firm innovation (von Hippel, 1988, Frankort et al., 2012, Rice et al., 2012, Colombo et al., 2011, Demirkan, 2018).

However, it is accepted that alliances carry coordination costs and risks of misappropriation, and these frequently diminish chances of success or preclude full acquisition of anticipated benefits (e.g. de Man and Duysters, 2005, Gkypali et al., 2017, Faems et al., 2010). A substantial body of literature finds a positive relationship between the extent of alliances and firm innovation performance, whilst other work identifies diminishing and even negative returns (Hoang and Rothaermel, 2005, Sampson, 2005, Laursen and Salter, 2006, Rothaermel and Deeds, 2006). As a result, a growing strand in the literature has examined the factors enabling firms to generate and capture value from alliances. One such factor is alliance experience accumulation: as firms develop greater experience in managing alliances they become better at coordinating cross-organisational tasks and knowledge flows (e.g. Sampson, 2005). Another factor that can improve performance in alliances, is developing formal and codified processes and routines for alliance management (for example, the establishment of dedicated alliance functions), which are argued to capture, or to be reflective of, firm-specific alliance management capabilities (Kale et al., 2002, Kale and Singh, 2009, 2007, Heimericks and Duysters, 2007, Sampson, 2005, Schreiner et al., 2009, Di Guardo and Harrigan, 2016, Shukla and Mital, 2018). Whilst these contributions offer useful insights, much the greater part of current theorising has been constructed via the use of cross-sectional data. Longitudinal explorations are scarce, thus we lack a nuanced understanding of the type of changes that occur within firms over time with respect to enhanced innovation potential from engaging in alliances.

The contribution of this paper is that, on the basis of a longitudinal approach, it examines how frequent engagement in alliances and expanding alliance portfolios (a compilation of contemporaneous alliances) impact on the likelihood of firm innovation; this offers a longitudinal approach that is lacking in the current literature (Draulans et al., 2003; Rothaermel and Deeds, 2006) with few notable exceptions (Di Guardo and Harrigan, 2016, Belderbos et al., 2015). A dynamic approach is appealing as it captures the impact on innovation of firm learning with respect to management of alliances. Such learning is evident in the use of past alliance experience to support conflict avoidance or management, and the effective coordination of knowledge sharing and communication with partners. Improved management can affect value capture in alliances especially as firms manage expanding alliance portfolios due to both potential of cross-partner asymmetries and knowledge redundancies, which are common in the bio-pharmaceuticals sector (Diestre and Rajagopalan, 2012, Caner and Tyler, 2013). The paper uses longitudinal econometric panel data analysis to explore its hypotheses. Secondary to this, we deploy a case analysis to capture the nuanced changes due to learning, shedding more light on the role of frequent engagement in alliances in compelling firms to direct their attention and resources in developing practices and routines for alliance management. This unpacks the antecedents to alliance capabilities and travels beyond

current understandings in relation to experience accumulation. As highlighted in a recent review (Wang and Rajagopalan, 2015), research on the antecedents to alliance and alliance portfolio capabilities is rather thin. This paper contributes to exploring this link further.

Our arguments are explored in the context of a unique, bespoke and specially assembled dataset, comprising the population of firms in the UK bio-pharmaceutical sector (110 firms 'alive' in 2003) and active during the period 1991 to 2001. The UK bio-pharmaceutical sector presents an ideal setting for investigation. The UK accounts for a significant share of the worldwide bio-pharmaceutical sector (McKinsey, 2014) and enjoys a revealed technological advantage (OECD, 2017) and comparative advantage (OECD, 2008) in this high-tech sector. Moreover, the UK is a prime example of the Liberal Market Economy variant detailed in the Varieties of Capitalism literature (Hall and Soskice, 2001, Hancke, 2009), where the socio-economic institutional configuration is associated with international competitiveness of industries that are characterised by radical innovations (such as the pharma and biotech industries).

The period 1991 and 2001 is perceived to be particularly apposite for our analysis as it exhibits several critical features: (a) a first instance and general upsurge in alliances (not only in the UK bio-pharmaceutical sector, but also in other sectors and territories (Kang and Sakai, 2000)); (b) the emergence of alliances as an integral component in firm R&D strategies in the bio-pharmaceutical industry (Hagedoorn, 2002, Demirkan, 2018, Powell et al., 2005) but also more generally (Rice et al., 2012); and, (c) the presence of significant variation - visible in terms of identifiable peaks and troughs in alliance activity - especially towards the end of the period (Hagedoorn, 2002). Moreover, this marks a paradigmatic era of new technology evolution, with new entrants and established firms developing capabilities in biotechnologies through alliance activity (Hopkins et al., 2007): thus it provides a historical backdrop that aids understanding of development of similar technologies, for example, nanotechnologies (Rothaermel and Thursby, 2007).

The remainder of this paper is structured as follows. Section 2 sets-out the theoretical background to the study and reviews the literature on alliance experience and alliance/alliance portfolio capabilities. Sections 3 and 4 develop our hypotheses. Section 5 discusses our sample, data sources, and methodological considerations and details the variables for our longitudinal econometric analysis. Section 6 is dedicated to estimation and results, and Section 7 provides results from post-estimation robustness checks. Section 8 discusses our findings together with the case study analysis and Section 9 highlights the implications of the study for management theory and practice.

2. Theoretical background: Alliance experience and alliance capabilities

To explain heterogeneity with respect to firm's abilities to benefit from alliances, the alliance literature resonates strongly with knowledge and capability based theories of the firm (e.g. Kogut and Zander, 1992, Helfat and Peteraf, 2003). Here, we adopt a perspective that is informed by both evolutionary theory of the firm (Nelson and Winter, 1982) and dynamic approaches to the resource based view (RBV) (Helfat et al., 2007, Helfat and Peteraf, 2003). These approaches take a dynamic view of organisational development, emphasising the role of experience and knowledge accumulation in supporting improved management and coordination of organisational tasks and activities. Given their dynamic and longitudinal orientation, they are closely aligned with our own analytical approach, informing our exploration of the roles of alliance experience accumulation and frequent engagement in alliances in organisational learning and enhanced innovation.

Evolutionary theory argues that by repetitively engaging in organisational tasks, or by gaining experience, organisations benefit from efficiency improvements as a result of 'learning-by-doing'. As firms follow different paths in accumulating and making sense of experience, they become heterogeneous in their abilities to carry out similar organisational activities. Experience assists firms in assessing which processes and practices are likely to perform better or to confer improved results, by judging on similar situations in the past. Organisations gradually create routines to efficiently coordinate organisational activities and develop capabilities to achieve outcomes important for competitive advantage (Dosi et al., 2000, Winter, 2000, 2003, Schilke and Goerzen, 2010, Nelson and Winter, 1982). Experience accumulation is an antecedent to developing capabilities; however, there can be a deliberate and conscious process of organisational learning as firms make investments in time, resources, training and knowledge to further improve their capabilities (Zollo and Winter, 2002), or to improve them through reflecting on newly acquired experience (Helfat and Peteraf, 2003).

Dynamic approaches to RBV are illuminating on the process of capability development by suggesting that there is an evolutionary path to their creation whereby capabilities emerge and improve through several developmental stages (Helfat and Peteraf, 2003). First, there is a 'capability founding' stage wherein organisations realise the need to develop a capability to meet desirable objectives and to orchestrate joint organisational action towards meeting these. Second, is a 'capability development' stage: here improvements to capabilities arise from a range of factors including further experience accumulation, investments in capital, organisational processes and learning mechanisms. Experience accumulation is crucial to both 'founding' and 'development' stages of a capability development. A third stage, 'capability maturity' is also identified: in this phase capabilities may be replicated, retrenched, renewed, redeployed or re-combined with other capabilities.

Even though alliances differ compared to other organisational tasks, in that firms collaborate with different partners in agreements with varying content, purpose and governance structure, gaining experience in managing alliances can lead to superior coordination, value creation and capture in alliances (Kale and Singh, 2007, Heimeriks and Duysters, 2007). Alliance experience is found to enhance the performance of alliances between recurrent partners, as firms use their experience and routines developed during their first interactions in managing subsequent collaborations within the dyad (Zollo et al., 2002). Moreover, firms mobilise experience and lessons gained across alliances with different partners (Anand and Khanna, 2000), with partner-specific alliance experience making a greater contribution to performance compared to general (i.e. non-partner specific) experience (Gulati et al., 2009).

Alliance experience (a firm's cumulative number of alliances) is an antecedent to both superior coordination of alliance tasks (alliance capabilities), and to the efficient management of synergies and redundancies across alliances in alliance portfolios (alliance portfolio capabilities) (for a review see Wang and Rajagopalan, 2015). Kale and Singh (2007) were the first to detail how firms proactively learn from their alliance experience by externalising, codifying, diffusing and internalising individual and group-level alliance know-how. A stream within the alliance literature explores the link between cumulative alliance experience, the development of dedicated alliance management functions and other processes and practices connected with upgrading alliance management routines (Kale et al., 2002, Heimeriks and Duysters, 2007, Kale and Singh, 2007). Alliance functions reflect alliance capabilities and can lead to superior outcomes from alliances. Alliance experience indirectly affects firm performance via such capabilities, indicating that dedicated alliance functions embody and absorb the impact of alliance experience, suggesting that firms leverage all the learning gained from experience in their alliance management functions (Kale et al., 2002). Other research suggests that alliance experience directly influences both financial (Kale et al., 2002, Anand and Khanna, 2000) and non-financial outcomes such as innovation performance (Sampson, 2005), and that this is in addition to any impact conferred by dedicated alliance functions, suggesting a complementary relationship between the two (Heimericks and Duysters, 2007). Indeed, systematic alliance practices are improved through training, mentoring programmes and external consulting. Such learning processes aim at introducing new alliance management practices and/or at improving existing ones in response to dissatisfaction with current performance (Zollo and Winter, 2002).

The following section revisits existing but still contested hypotheses on the expected impact of alliance experience on firm innovation performance. We also develop our hypothesis on the impact of alliance frequency, which from a longitudinal perspective can be better positioned to capture

nuancing and conditioning factors that reflect the impact of organisational learning from alliance experience on innovation.

3. Alliance experience and firm returns from alliances

Firms with greater experience can draw from a greater pool of situations about what has worked in practice, when making decisions and inferences with respect to the performance of organisational practices (Levitt and March, 1988, Argote et al., 1990). Alliance experience (cumulative number of alliances) improves firms' abilities: to manage and coordinate alliances, to improve coordination of inter-organisational relationships and joint tasks, to form efficient arrangements for knowledge sharing, to deal effectively with unforeseen contingencies, and to identify ways to overcome and resolve inter-partner conflict (Anand and Khanna, 2000, Sampson, 2005, Belderbos et al., 2015, Rothaermel and Deeds, 2006). Due to the link between alliance experience and organisational learning, experience is seen as a fundamental antecedent to both alliance and alliance portfolio capabilities (Wang and Rajagopalan, 2015, Kale and Singh, 2009, Shukla and Mital, 2018). Literature suggests that firms may not be in a position to benefit from learning from experience and superior coordination of alliances, when facing power asymmetries and resource dependence in alliances. Conflict is more frequent in such alliances which affects value creation and capture, especially for the weak partner as they are at a comparative disadvantage (Diestre and Rajagopalan, 2012). Power asymmetries are likely in the bio-pharmaceutical sector, as large pharmaceutical firms may be collaborating with small-dedicated biotech firms and due to their longer commitment to alliances and historic investments in downstream capabilities may be at a comparative advantage in deriving value from alliances (Caner and Tyler, 2013).

We argue that by gaining greater alliance experience, firms gradually establish more fruitful conditions for effective knowledge sharing with their partners, and generate a basis for circumventing or resolving alliance conflicts. Because conflicts are more likely to occur in the bio-pharmaceuticals sector we expect that the higher the levels of experience the more likely the firms are to capture value from alliances and enhance their likelihood of innovation.

Hypothesis 1: Alliance experience accumulation positively affects a firm's likelihood of innovation

A body of work suggests that efficiency improvements from experience accumulation make a gradually diminishing contribution to firm performance. There are two likely explanations for this. First, as firms form more alliances and accumulate greater experience, the contribution of any

additional alliance to accumulated learning becomes increasingly reduced. This has been identified irrespective of type of partner and across upstream, downstream and horizontal alliances (Rothaermel and Deeds, 2006). Firms may experience diminishing returns when managing an increasing number of alliances due to the increased costs associated with identifying suitable partners, establishing and maintaining contracts, difficulties in absorbing knowledge from diverse sources, conflicts due to knowledge asymmetries and increased possibilities of knowledge redundancies (Diestre and Rajagopalan, 2012, Rothaermel and Deeds, 2006, White and Lui, 2005)

A second likely explanation is that the value of lessons learned from cumulative experience depreciates over time as knowledge becomes increasingly obsolete (e.g. Argote et al., 1990). Past knowledge may depreciate as task requirements change over time. Further, the value of past lessons may dissipate gradually (or suddenly) as a result of employee turnover or a failure to store intelligence in organisational routines, or in a way that permits its re-application (Levitt and March, 1988, Dutton and Thomas, 1984). Unless firms make appropriate investments in retaining and leveraging lessons learned from their experience, its effects will increasingly dissipate.

Research in the alliance literature has demonstrated a positive and linear relationship between alliance experience and firm-level indicators of financial (Anand and Khanna, 2000) and innovation performance (Shan et al., 1994). Only a slender body of work has explored diminishing returns to alliance experience. Hoang and Rothaermel (2005) find that, whilst alliance experience of small firms positively impacts the performance of their joint projects with large firms, the alliance experience of large firms makes no significant impact on their joint alliance project performance. Benefits stemming from alliance experience differ between small and large firms because they are positioned at different levels along the diminishing/concave alliance experience curve. In related research, Sampson (2005), commenting on patenting performance in the telecom equipment industry, identifies similarly diminishing returns to cumulative alliance experience, which she attributes to a diminishing contribution of distant experience, suggesting that distant alliance experience plays less important role than recent experience in efficient management of alliance portfolios (Shukla and Mital, 2018). As a consequence, we derive the following hypothesis:

Hypothesis 2: The effect of cumulative alliance experience on likelihood of innovation exhibits diminishing marginal returns: as alliance experience accumulates, its contribution to the likelihood of firm innovation decreases

4. Frequent engagement in alliances as an antecedent to alliance capability

Deciphering, coding and measuring capabilities is notoriously difficult (Godfrey and Hill, 1995). As a result, the alliance literature has, in the main, relied on identifying alliance management practices (e.g. alliance functions) as a way of documenting alliance capabilities (Kale et al., 2002, Kale and Singh, 2007, 2009). An exception is found in the work of Rothaermel and Deeds (2006). They explore an inverted U-shaped relationship between cumulative alliance experience and new product development. They argue that, as the inflection point of the inverted U-shaped curve corresponds to the level of experience beyond which firms start experiencing inefficiencies in alliance management, it can reflect the level of their alliance capability.

The notion that dedicated alliance management functions reflect alliance capabilities has being challenged in recent literature. First, anecdotal evidence suggests that firms establish dedicated alliance functions only after engaging in alliances over a protracted period, and after initiating a substantial number of such agreements (Kale and Singh, 2009). As a result such functions cannot reflect alliance capabilities, particularly when capabilities are at the initial stages of their development. Research indicates that firms – especially those motivated by perceived market signaling requiremets - may establish dedicated alliance functions as a result of mimitisism or isomorphism (Heimeriks, 2010)[1]. Indeed, isolated mechanisms for institutionalising learning (e.g. dedicated alliance functions) from cumulative alliance experience may prove to be less effective compared to mechanisms designed to integrate and embed alliance knowledge throughout the organisation (Heimeriks et al., 2015).

Despite some tentative and tangential work, explorations with respect to the underlying factors that lead firms to become aware of the need to leverage their alliance experience in developing a capability, and to invest efforts and resources in processes for deliberate learning from alliances are sparse in extant literature (see Wang and Rajagopalan, 2015). We contend that the first instances of frequent engagement in alliances can form such underlying factors and we turn to evolutionary theory and dynamic RBV to assist in elaborating our argument. Specifically, we suggest that frequent engagement in alliances may compel firms to found an alliance capability development lifecycle, as they both protract the period of engagement in alliances, and engage more substantially in this activity (Helfat and Peteraf, 2003). By engaging in alliances frequently, firms expand, augment and renew their stock of cumulative alliance experience. Frequent engagement in alliances induces firms to invest in developing higher order routines and practises to initiate purposeful and directed

[1] Heimericks (2010) distinguishes between institutionalising mechanisms for alliance management on the one hand (i.e., those that codify alliance learning and standardise it in routine approaches), and integrating mechanisms on the other (i.e., those for sharing and diffusing within the organisation recent insights in alliance management).

organisational learning. Developing processes for alliance management and practices for their further improvement requires managerial commitment, commitment that is highly demanding in terms of time and employee resources (Winter, 2003, Dosi et al., 2000, Winter, 2000). As a result, firms need to justify the allocation of resources to building dedicated routines for alliance management: frequent task reoccurrence can trigger and motivate firms to deploy resources in such a direction. It can also justify such investments to external stakeholders, building internal support and commitment to the purpose.

Sparse empirical literature explores the role of frequent engagement in alliances in developing alliance capabilities (see Wang and Rajagopalan, 2015 for a review). There is a particular dearth of longitudinal studies in this field (Draulans et al., 2003, Rothaermel and Deeds, 2006). Research on CIS longitudinal Spanish data indicates that persistent and not sporadic collaboration exhibits a systematic positive relationship with firm innovativeness, which runs parallel to our argument (Belderbos et al., 2015). Moreover, firms that renew and expand their collaborations and alliances over time become more embedded in a network and experience higher growth over time (Powell et al., 2005). At the cross-sectional level, there is only limited research that links larger alliance portfolios to the development of alliance capability (as this is reflected in alliance management practices). Larger alliance portfolios are associated with the use of enhanced alliance management practices and processes, with the latter being linked to improved firm performance (Heimericks et al., 2009). Our longitudinal approach, capturing the tendencies of firms to engage in alliances more frequently over time, complements such accounts which are based on the role of stock measures of alliance experience in firm performance (Kale et al., 2002; Heimeriks and Duysters, 2007, Kale and Singh, 2007). Therefore we propose that firms that engage in alliances frequently are more likely to innovate compared to those firms that (a) engage in alliances irregularly or sporadically, or that (b) retain a static engagement and a stagnating alliance portfolio over time.

Hypotheses 3: Frequent engagement in alliances and the ensuing expanding alliance portfolios positively affect firm likelihood of firm innovation over time

5. Sample and methods

5.1 Sample

We test our hypotheses on a panel dataset observing the population of firms in the UK bio-pharma sector (110 firms in 2003) during the period 1991 to 2001. The empirical exploration in this paper relies fundamentally on econometric analysis. However, secondarily the paper employs a case

analysis to shed further light on - and nuance - some of its arguments. To identify our sample, we used two editions of the UK biotechnology directory (Coombs and Alston, 2000, 2002). The directory lists all firms in the sector that undertake research using biotechnologies. It provides a more comprehensive account of the firms in the UK bio-pharma sector than that available via the use of SIC classifications, as biotechnologies are used by firms from a range of industries in the life sciences as broadly described (Walsh, 2004). To form our working sample, we used the 'Who Owns Who' directory to identify all firms that were active in 2003. Out of that list, we identified 110 firms that publish accounts in FAME[2].

For the sample of 110 firms, we collected data on alliances from ReCap.com and BioScan, the two most popular sources of alliance data in empirical research on this sector (e.g. Deeds and Hill, 1996, Schilling, 2009). The databases report alliances established in the bio-pharmaceutical sector for innovation purposes, including R&D alliances, research alliances, and alliances for technology licensing and product development[3].

Innovation is crucial to firm survival and prosperity in the bio-pharmaceutical sector and patents are perceived as an appropriate proxy for innovations due to the science-based nature of the sector (e.g. Pavitt, 1984). Moreover, patents are an appropriate indicator to capture firm-level returns from innovation alliances (Demirkan, 2018, Shan et al., 1994, Sampson, 2005). We collected data on patents granted to the 110 firms in our sample between 1991 and 2001 by the UKPTO through the publicly-available database Esp@cenet. Via deployment of boolean searches, it was possible to assemble a comprehensive list by matching both the name and the address of firms in our sample with those of the patent assignees (Arora et al., 2011). For firms in our sample that belong to MNEs with non-UK based HQs, we examined information on inventor location, and allocated any patents assigned to the MNE HQ with UK-based inventors to the UK-based subsidiary in our sample. Since our research focuses on UK-based firms, the UKPTO is perceived to be an appropriate source for the collection of patent data. Filing patent applications at national patent offices is less costly (in terms of application and renewal fees) and less time consuming when compared with international patent applications. As international applications also involve costs of unfamiliar IP regulations and legal frameworks, many firms - at least those with constrained resources - are more likely to patent at national patent offices than internationally (Archambault, 2002). Finally, information on firm accounts was obtained

[2] FAME provides financial information relating to all UK listed companies.

[3] Both databases are literature based, a factor that raises some concerns with respect to possible under-representation of alliances of smaller value or those involving smaller firms. Confidence is bolstered however, by recent research that demonstrates the results of empirical studies to be independent of the use of particular alliance databases (Schilling, 2009).

from FAME, and information on investments in R&D was gathered from Thomson's Analytics and the UK DTI's R&D Scoreboard.

5.2 Methods

Patents take positive integer values, making count dependent variable models, such as the Poisson and Negative Binomial, appropriate (Greene, 2003). Instead of count dependent variable models, we employ discrete dependent variable models as they permit the capture of factors that alter firm abilities enabling them to perform over a threshold level: successful filing of a patent (Long, 1997). This is better aligned to the core aim of this work, which is to explore whether frequent alliance engagement is linked to organisational learning in alliance management (and alliance capabilities), reflected in firms exhibiting over threshold performance (Hoang and Rothaermel, 2005).

Due to the longitudinal dimension of panels, we can explore factors that affect firms' changing abilities to innovate over time (fixed effects specification), as well as factors that can explain cross-firm variation in innovation abilities (random effects specification). The former, *dynamic* consideration of panels is of particular interest in this paper, as explained above. The fixed effects specification has a further appeal as its estimates are not based on the assumption of strict exogeneity of the independent variables (Greene, 2003, Baltagi, 1995), which is desirable, as decisions to form alliances may not be independent of past innovation performance (Colombo and Garrone, 1996, Gkypali et al., 2017).

To explore further the nuanced factors underlying the development of alliance capabilities, we report on the findings of an in-depth case analysis that explores the link between frequency of engagement in alliances, and the development of practices and processes to manage alliances, an indication of alliance capabilities (Schreiner et al., 2009, Kale and Singh, 2007); this is a secondary analysis providing an illuminating complement. The case focuses on a UK bio-pharmaceutical firm that intensified its engagement in alliances particularly after the early 1990s when it started to invest in biotechnology R&D. Interviews were conducted in 2005 as the firm was forming a dedicated alliance function and entailed detailed reflection on the factors that underpin the creation of processes established to improve efficiency in alliance management. The processes identified were matched with those identified in existing literature on alliance capabilities (Kale et al., 2002, Kale and Singh, 2007, 2009, Heimericks and Duysters, 2007). The case is based on interviews with directors of alliances and intellectual property, with a long working experience with the case firm and focused on alliances that involve cooperation in research and that have led to patents. All materials and associated analyses were reviewed and approved by the interviewees.

5.3 Variables

Patents (dependent variable)

To test our hypotheses we create a dummy variable that is equal to 1 for each firm that is granted a patent at year t (and equal to zero otherwise). We use a patent dummy variable as we aim at capturing the impact of alliance experience in enabling firms to perform over a threshold, i.e. to innovate. To track the firm's innovation activities over time, we use patent filing dates. Filing dates have certain advantages over publication dates: first, they better reflect the originating time of innovations; and, second, they are not influenced by regulatory changes or fluctuations in resource availability in patent offices over time, as these can delay publication dates (e.g. Jaffe, 1986). Patents are widely used to capture firm returns from innovation alliances (Sampson, 2005, 2007, Shan et al., 1994, Demirkan, 2018).

Alliance experience

Research has explored the role of alliance experience in improving financial returns of firms from alliances (Kale et al., 2002), alliance project success (Hoang and Rothaermel, 2005), returns to firm innovation performance (Sampson, 2005, 2007, Belderbos et al., 2015, Di Guardo and Harrigan, 2016) and number of products under development (Deeds and Hill, 1996, Rothaermel and Deeds, 2006). Studies have operationalised alliance experience as a stock variable reflected either by the cumulative number of alliances formed throughout a firm's history (Kale and Singh, 2007, Hoang and Rothaermel, 2005, Kale et al., 2002, Rothaermel and Deeds, 2006), or by the cumulative number of years of experience in engaging in alliances (Rothaermel and Deeds 2006). Only a handful of these studies consider diminishing (Sampson, 2005) or non-linear (Rothaermel and Deeds, 2006) relationships between alliance experience and firm returns from alliances and most studies base their estimates on cross-sectional data (an exception is Kale et al., 2002).

Following existing literature, we operationalise alliance experience at each year *t* as the cumulative number of alliances throughout a firm's history. To aid interpretation of results, and following recent contributions (Lavie et al., 2011) we use one year lagged values of the above variable to more accurately capture the effect of cumulative alliance experience. Our variable is left-censored to 1991, the start year for our sampling. This is experienced elsewhere in alliance literature (e.g. Kale and Singh, 2007). Also, because in our study 87% of total alliances from 1979 and 2001 fall within the 1991-2001 period, left censoring is not introducing considerable bias. As is customary in the literature (Sampson, 2005), we use the natural logarithmic transformation of cumulative alliance experience to test for diminishing returns (hypothesis 2). As a robustness check, we test for a concave relationship (inverted U-shaped) by using both the linear and quadratic values of the cumulative number of

alliances: again, this approach follows relevant literature (e.g. Deeds and Hill, 1996, Rothaermel and Deeds, 2006)[4].

Frequent engagement in alliances and expanding alliance portfolios

To explore the effects of frequent engagement in alliances on firm abilities to innovate, we measure the total number of on-going alliances that a firm manages simultaneously at any point in time. As alliances last for several years, this requires information on alliance duration which is not available via the alliance data sources consulted in this study (RECap.com and BioScan). As lack of information on alliance duration has also been encountered in other work, we follow established tradition and rely on estimates of the average duration of alliances, i.e., five years (Kogut, 1988, Di Guardo and Harrigan, 2016). Therefore, we operationalise frequent engagement in alliances by calculating the number of alliances a firm manages at any given point in time by considering that alliances last on average for five years. Increases in this variable reflect the tendency of firms to engage more frequently in alliances over time, and on average, to initiate more alliances than they terminate, managing potentially an expanding portfolio of on-going alliances. As the use of a blanket measure for alliance duration might be considered simplistic, we cross-validated this information with alliance managers in the sector, and it was considered an acceptable approximation for the duration of the majority of alliances. We also performed robustness checks by using different estimates for alliance duration as detailed in our analysis.

Control variables

For parsimonious empirical models, we use the most appropriate control variables that have been employed in the literature on alliances and innovation. First, we account for the effects of well-established indicators of firm innovation, such as investments in R&D and firm size (Griliches, 1990) as they can influence firm abilities to innovate. We used a measure of R&D intensity that captures the amount of R&D expenditure per employee. Firm size is captured by annual turnover and we include a natural logarithm to overcome the possible problem of skewed distributions. Second, and following relevant research (Zollo et al., 2002), we account for differences in the content of alliances, as it influences innovation opportunities in alliances and affects firm performance (e.g. Anand and Khanna, 2000). Therefore, we include a dummy that takes the value of one when the focal firm establishes an

[4] As explained in the results section, the results we obtained from both operationalisations are not substantially different.

alliance that involves R&D, and the value of zero for each year that a focal firm establishes alliances that do not involve R&D.

6. Estimation and results

Table 1 presents descriptive statistics and bivariate correlations.

Insert Table 1 about here

The panel is unbalanced, as a result of either missing information or the inclusion of less-mature dedicated biotechnology firms (i.e. a third of firms in the sample were established after 1995). The unbalanced dataset includes firms observed for a maximum period of 10 years and others for as little as 4 years. On average, firms are observed for approximately 7 years (the range is from 6.6 to 7.4 years across the three estimated models) and form 8.28 alliances between 1991 and 2001.

We estimated both the Fixed and Random Effects specifications (FE and RE respectively) of the Logit model for panel data for all three models (Greene, 2003, Baltagi, 1995)[5]. Results are obtained in STATA© 11. The Rho parameter is significant across all three models, indicating significant cross-firm heterogeneity. As the Hausman (1978) specification test has limited discerning power in discrete dependent variable models, we assess the relative merits of the two specifications on a conceptual basis and for reasons discussed in the methods section we present Logit FE estimates. Moreover, the residuals of the FE specification are corrected for potential heteroscedasticity (White, 1980, Baltagi, 1995).

Insert Table 2 about here

Based on model Chi^2 statistics in Table 2, all three models are significant at 5% levels and above. This suggests that our variables have a significant interpretative power with respect to the likelihood of firm innovation. We find support for all hypotheses. In Model 1, the cumulative number of alliances positively affects firm's likelihood of innovation over time, but levels of significance are

[5] The Probit model provides an alternative specification to Logit. However, both models provide the same results in terms of significance levels (Long, 1997).

low (10%). Our results are consistent with studies showing a positive relationship between cumulative alliance experience and firm innovation, but at low significance levels (Hagedoorn and Schakenraad, 1994, Shan et al., 1994).

The FE estimates of Model 2 provide support for diminishing returns to firm innovation from cumulative alliance experience, with the corresponding variable being positive and highly significant. The results of Model 2 are consistent with findings testing similar hypotheses in cross-sectional settings in the US bio-pharmaceutical and the telecom equipment industries (Hoang and Rothaermel, 2005, Sampson, 2005). Our results are robust to alternative operationalisations, as reflected by exploring concave relationships (inverted U-shaped), via use of both linear and quadratic values of cumulative alliance experience, with estimates (both FE and RE) confirming non-linear diminishing returns to likelihood of firm innovation. To unpack the extent of diminishing returns we estimate the inflection point based on estimates of the curvilinear relationship; this is equal to 127.515 points of cumulative experience, which corresponds to firms managing 18 alliances annually (average length of time per firm in the panel is 7 years). Our results imply that at such a level of annual alliance activity, firms will accrue no additional benefits from gaining more experience in managing alliances. It should be noted that in our sample the average number of new alliances formed every year is 8.28, which suggests that the majority of firms in our sample are below the optimal level of alliance engagement. The concluding section discusses the implications of this.

Model 3 provides support for our third hypothesis. The coefficient of the core independent variable is positive and significant (it marginally fails to pass the highest 1% level of significance). Model 3 suggests that firms that establish alliances frequently and that continuously manage an expanding portfolio can enjoy improved likelihood of innovation. This provides fresh insights as, to date, there has been a scarcity of longitudinal studies in the literature (see Draulans et al., 2003, Rothaermel and Deeds, 2006). As a test of robustness, we estimated Model 3 by using 4 and 6 years as the average duration for alliances. The results remained robust to different operationalisations. Among the control variables, firm size is positively and significantly associated with firm's likelihood of innovation in Models 1 and 3. Investments in R&D per number of employees is negatively associated with likelihood of firm innovation but only in Model 2. Alliance content is insignificant across all three models.

Finally, all three model estimates are robust to different measures of the control variables. For example, all models lead to the same outcomes in terms of significance when controls are collapsed to dichotomous variables indicating above and below average firm size and intensity of investments in R&D per number of employees. A further robustness check is undertaken to examine whether our results are sensitive to the statistical assumptions of the distribution followed by the error term in the

Logit and Probit specifications. The Probit model only provides RE estimates for panel data (STATA© 11) and these further confirm our results. Moreover, we estimate our model specifications with the Negative Binomial model to explore differences between our dependent variable and a count variable capturing innovation performance with the number of patents. Both FE and RE estimates confirm our hypotheses.

7. Tests of Robustness[6]

The results suggest that there are diminishing returns to cumulative alliance experience. This can signal that ageing experience contributes less to current outcomes and that recent experience may have a higher contribution (Shukla and Mital, 2018, Sampson, 2005). Following Sampson (2005) we explore the contributions of recent and past alliance experience. We develop a set of variables capturing alliance experience between 1 and 6 years prior to our year of observation. So, for example, in 2001 alliance experience of 1 year corresponds to the number of alliances initiated in 2000 and alliance experience of 2 years corresponds to those initiated in 1999 and so on. None of these variables appear to be significant, with the exception of alliance experience of 4 years prior to the year of observation, which appears with a negative and significant sign. Therefore, the diminishing returns to cumulative alliance experience identified in our paper cannot be attributed to decreasing contributions of distant experience. Our results most likely reflect that firms, by just forming more alliances and learning from experience how to improve alliance management and coordination, cannot experience improved efficiency *ad infinitum*.

With regards to Hypothesis 3 we undertake further estimations to isolate the impact of frequent engagement in alliances from that of portfolio size. We break down the variable testing Hypothesis 3 into two components. First, capturing changes in the frequency of forming alliances over time, we construct a variable reflecting a decreasing, static and increasing trend in alliance portfolios (the variable takes the values of: -1, 0 and 1 respectively and refers to comparisons between the current and the previous year). Second, we include a variable to capture the number of new alliances formed within every year (one year lagged values are used in the models). Our results show that the trend variable has a negative sign while the annual figures of newly formed alliances appear with a positive and significant sign (both for the Logit and the Negative Binomial models and the FE and RE specifications). It is worth noting that when the values of the trend variable are lagged by one year, their impact becomes insignificant (that is, they retain a negative sign). This means that only the

[6] Results are available upon request.

contemporaneous impact of alliance frequency on innovation is negative, implying that when firms expand their alliance portfolio there is an immediate adverse effect. This may result from immediate strains on their resources and cognitive abilities, which however, cease to have an adverse effect within a year's time. The results remain the same when the trend variable is substituted with a dummy variable capturing only increases in the frequency of forming alliances between current values and those of the previous year.

Finally, we isolate partner-specific alliance experience from general (i.e. non-partner specific) experience to further explore the importance of alliance management learning within partner dyads and in alliance portfolios. None of these variables has a significant effect, suggesting that the separation lacks interpretative power.

8. Discussion

The paper contributes to the literature on the role of alliances in innovation and alliance capabilities by using a longitudinal analysis which enables capture of the impact of organisational learning in managing and coordinating alliances on innovation. As it is difficult to capture learning, the paper uses a longitudinal approach to capture dynamic changes within firms and it observes learning through its impact on outcome variables such as innovation. The paper adds to a slender body of work exploring antecedents to firm level alliance capabilities and their impact on enhancing firm's abilities to innovate (for a review see Wang and Rajapolagan, 2015).

First, we find that the impact of learning from gaining greater alliance experience in coordinating alliances and portfolios on firm innovation is positive but of weak significance. This is an important finding, as alliances in the bio-pharmaceutical sector can be characterised by power asymmetries and unbalanced resource dependence between partners, which are likely to create conflicts affecting the creation and appropriation of alliance value (Diestre and Rajagopalan, 2012, Caner and Tyler, 2013). The period of our study forms the first window of exploitation of biotechnologies via alliances which potentially creates disincentives to collaborating firms to behave opportunistically, as joining forces during this close to pre-competitive stage could be more beneficial than not (Powell et al., 2005).

Second, our analysis proceeds by exploring the factors that affect learning in managing and coordinating alliances in this sector. The first arm to this exploration sheds light on the role of cumulative-historic experience in enhancing innovation performance, while the second arm focuses on the role of such experience as an antecedent to the creation of capabilities to manage interactions with alliance partners and to create synergies and minimise redundancies in alliance portfolios. In that endeavour, we first confirm diminishing returns to the benefits that can be accrued by gaining

alliance experience for more effective management of alliances and capturing innovation returns. This supports a thin body of research which suggests that learning from gaining experience cannot confer benefits *ad infinitum* (e.g. Rothaermel and Deeds, 2006; Sampson, 2005). Our in-depth exploration shows that this cannot be attributed to diminishing contributions of ageing experience as identified in other work (Sampson, 2005, Shukla and Mital, 2018). It could be attributed to failure of firms to capture learning in a systematic way, or to costs associated with identifying more partners, establishing more agreements, and coordinating increased diversity (White and Lui, 2005, Rothaermel and Deeds, 2006).

Our last set of findings show that engaging in alliances more frequently over time, with firms managing an expanding portfolio, by forming more alliances than they terminate, enhances firms' likelihood of innovation. Our longitudinal approach is consistent with other work showing that persistence in collaboration has a positive impact on firm innovation as opposed to sporadic collaboration (Belderbos et al., 2015). Longitudinal explorations are currently almost absent in alliance literature, and their potential contribution has been particularly welcomed (Draulans et al., 2003, Rothaermel and Deeds, 2006), specifically as they might shed further light on the type of changes that can occur within firms, in particular, with respect to the dynamics of learning on alliance management and how it enhances innovation potential. Contributions within evolutionary theory (Winter, 2000, 2003) argue that frequent engagement in organisational tasks is linked to capability development, while the dynamic resource-based view (Helfat and Peteraf, 2003) argues that capabilities develop through several stages: experience accumulation compels firms to recognise the need to establish a capability, and this initiates a process of systematic learning and alliance management. Our results clearly pertain to this literature and specifically on how alliance experience forms an antecedent to alliance and alliance portfolio capabilities (Wang and Rajagopalan, 2015). To explore, in a situated and more granular fashion, whether frequent engagement in alliances and a dynamically expanding alliance portfolio contribute to the development of alliance capabilities, we conducted a detailed case analysis as a complement to our econometric analysis. The case analysis explores the link between an increasing engagement in alliances and the development of novel or changed practices and processes for alliance management, i.e., those factors that normally sit within the "black-box" of alliance capability studies (Anand and Khanna, 2000, Heimeriks and Duysters, 2007, Kale and Singh, 2007).

The case analysis clearly reveals such a relationship. First, it shows that alliance management practices and routines are established after alliances become an integral part of firm R&D and innovation strategy and firms intensify and commit to alliance activity. As the Alliance Director interviewed for our study stated: "*…we have standardised approaches for contractual compliance*

[with respect to alliances]… *it's inconceivable to me that one wouldn't have, and yet five years ago we didn't… You've got one deal and you do it however you do it which largely depends on who you employ and who it's* [the alliance] *with… I am not sure how many deals you need to have before you get yourself a standardised process but it's probably substantially more than ten or twenty…".*[7] Second, several of the practices identified in the extant literature that are used to institutionalise and diffuse alliance management learning (namely, employment of alliance professionals, use of alliance metrics, creation of databases to solicit potential alliance partners, and establishment of processes to monitor alliance performance) are deployed by the case firm (Heimericks and Duysters, 2007, Kale and Singh, 2007). Ten years after intensifying alliance engagement, it developed a dedicated alliance management function to coordinate alliance activity and engage in monitoring and improving existing alliance management practices.

The case analysis illustrates the links between frequent engagement in alliances and the ensuing expanding the alliance portfolio, with the motivation to invest resources in developing firm-specific capabilities for alliance management. It also reflects the time required to recognise that alliance management can be improved via the development of specific and specialist processes for the governance of cross-partner interaction (a finding that resonates strongly with existing literature (Kale and Singh, 2009)). In addition, the case reflects the requirement for firms to continuously review and develop their capabilities in order to confront new challenges and intensified competition. Indeed, the case analysis, combined with the findings of our econometric exploration, suggest that renewing alliance experience and committing to forming more alliances over time are crucial in enabling firms to create and capture value in alliances.

9. Implications for management theory and practice

Our research contributes to the literature on the antecedents of alliance and alliance portfolio capabilities and on the conditions that shape superior firm outcomes from alliances, such as innovation. It suggests a need to delve into the antecedents to alliance capabilities, a thin body of research and to identify nascent factors that provide potential foundations for alliance capability development (Helfat and Peteraf, 2003), shifting attention away from the role played by alliance management practices (such as dedicated alliance functions) that have dominated existing research. This is particularly important as firms may establish such practices during the advanced stages of the alliance capability development process (Kale and Singh, 2009), and as such they may not appropriately reflect the foundational stages of alliance capability development. Here we echo calls to delve deeper in understanding alliance management capabilities and the antecedents to alliance

[7] Interview with Alliance Director.

portfolio capabilities (Wang and Rajagopalan, 2015), especially in the context of alliances involving a higher learning potential (Heimeriks, 2010). Moreover, recent research shows that codification of alliance learning and systematic approaches to alliance management contribute to efficient partner selection and alliance termination, but may restrict flexibility and adaptability which are important for efficient management during the course of the alliance (Heimeriks et al., 2015, Wang and Rajagopalan, 2015).

Our research has several implications for managerial practice and policy. First, we find that there are diminishing returns to benefits in terms of enhanced innovation accruing from gaining greater alliance experience. Specifically firms reach a plateu at 18 alliances in annual terms, suggesting that on average this is the optimal level of alliance engagement for enhancing firm likelihood of innovation. This has implications for managing alliance portfolio size for innovation efficiency (e.g. Hoffmann, 2007, Demirkan, 2018). On average firms in our sample are below the optimal level of alliance engagement (forming 8 alliances annually). This suggests that innovation likelihood can be marginally enhanced by expanding alliance engagement. This is in line with findings of other research (Rothaermel and Deeds, 2006; Sampson, 2005; Hewitt-Dundas and Roper, 2018) which in the context of micro-businesses for example, shows that sub-optimal engagement can be attributed to reluctance of firms to cooperate due to fear of trustworthiness and lack of knowledge on benefits of collaboration and partner capabilities (Hewitt-Dundas and Roper, 2018). This emphasises our findings with respect to the need to faciliate a culture of systematic management of alliances. It also supports research suggesting the need for policy interventions, for example in the form of intermediaries, which can support and encourage firms to establish collaborations and manage openness (Howells, 2006). This is not only due to the benefits of collaboration to firm innovation but also due to the positive externalities from openess, suggesting broader economic and societal benefits (Roper et al., 2013).

At the firm level, our results suggest that it is important for firms to replenish their alliance portfolios and to gradually form more alliances than they terminate over time if they wish to enhance their innovation likelihood. In the bio-pharmaceuticals sector where there is high rate of alliance formation, it is important for firm competitiveness and future growth that they renew and expand their networks (Powell et al., 2005). This is linked to firms becoming more aware of the need to make alliance management learning more systematic. Firms should use such systematic practices in a discretionary manner and should also consider altering and upgrading such practices to respond to the challenges and demands of new alliances. Although our results are specific in terms of sector and period, they derive from the examination of a paradigmatic period in the development of new technologies, and address the implications of changing innovation processes in an established industry. As such, they provide useful insights that assist understanding of trajectories and dynamics

in industries with similarities to biotech, for example, nanotechnology (e.g. Rothaermel and Thursby, 2007). Our aspiration is that our research will provide some re-focusing and clarity in an established field of study. We acknowledge that analysis of further sectors and periods will nuance our understanding of both the role of gaining experience in improving firm alliance management and in developing alliance capabilities, and hope that the ideas and methods explored above will assist in this ongoing quest.

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Table 1: Descriptive statistics and bivariate correlations (post-estimation sample) (SEE SEPARATE FILE)

Table 2: Logit estimates, dependent variable: patent dummy (SEE SEPARATE FILE)